NONLINEAR VALLEY AND SPIN CURRENTS FROM FERMI POCKET ANISOTROPY IN 2D CRYSTALS

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Controlled flow of spin and valley pseudospin is key to future electronics exploiting these internal degrees of freedom of carriers. Here we discover a universal possibility for generating spin and valley currents by electric bias or temperature gradient only, which arises from the anisotropy of Fermi pockets in crystalline solids. We find spin and valley currents to the second order in the electric field, as well as their thermoelectric counterparts, i.e. the nonlinear spin and valley Seebeck effects. These second-order nonlinear responses allow two unprecedented possibilities to generate pure spin and valley flows without net charge current: (i) by an AC bias; or (ii) by an arbitrary inhomogeneous temperature distribution. As examples, we predict appreciable nonlinear spin and valley currents in two-dimensional (2D) crystals including graphene, monolayer and trilayer transition metal dichalcogenides, and monolayer gallium selenide. Our finding points to a new route towards electrical and thermal generations of spin and valley currents for spintronic and valleytronic applications based on 2D quantum materials.